NEW EVIDENCE FOR TRITON AND HELION CLUSTERING IN NUCLEI

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Abstract

Normally one plots separation energies S_{1n} and S_{2n} as a function of neutron number N for a particular proton number Z or plot S_{1p} and S_{2p} as a function of Z for a particular N. Here we plot the separation energies a little differently: S_{1n} and S_{2n} as a function of Z for a particular N. The same with S_{1p} and S_{2p} as a function of N for a particular Z. A systematic study of these new plots brings out certain very interesting generic features which clearly indicate presence of triton ("t") $^{3}_{1}H_{2}$ and helion ("h") $^{3}_{2}He_{1}$ clustering in nuclei.

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In the study of nuclear structure, separation energies have played an important role and are continuing to do so in identifying new magic numbers in recent years [1-4]. In all such studies one normally plots separation energies S_{1n} and S_{2n} as a function of neutron number N for a particular proton number Z or plot S_{1p} and S_{2p} as a function of Z for a particular N.

We plot the separation energies a little differently here. We plot S_{1n} and S_{2n} as a function of Z for a particular N. The same with S_{1p} and S_{2p} as a function of N for a particular Z. We do a sytematic study of these plots for all the data available in literature at present [5]. Such plots have completely been ignored in literature. This is very unfortunate as these plots do contain huge amount of interesting and revealing information which has been missed so far. We shall show that these brings out certain very interesting generic features which as we shall find clearly indicate strong evidences of triton ("t") $_{1}^{3}H_{2}$ and helion ("h") $_{2}^{3}He_{1}$ clustering in nuclei

We study the whole range of data set available [5]. However as all this will take much more space than necessary for this paper, here we show a few representative plots. These are one and two neutron separation energy as a function of Z for N = 29 and 30 as plotted in Fig 1 and 2 below. All the plots of S_{1n} and S_{2n} as a function of Z for a particular N show similar features. The same with S_{1p} and S_{2p} as a function of N for a particular Z. We do a sytematic study of these plots for all the data. The features which we shall point out here are there in all the other plots. In fact we shall study here only those features which are generic of all such plots. Special studies of specific set of nuclei (which too would be very fruitful) shall be left for separate future studies.

Certain common feautres which stand out are as follows (The statements below are made in the context of the plot S_{1n} and S_{2n} as a function of Z for a particular N):

A. *For all even-even N=Z nuclei there is always a pronounced larger separation energy required with respect to the lower adjoining nuclei plotted.*

B. *For all odd-odd N=Z nuclei there is always a pronounced larger separation energy required with respect to the lower adjoining nuclei plotted.*

C. *For case* **A** *when Z number is changed by one unit, the separation energy hardly changes (sometimes not at all). But when this number is changed*

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by two units, another pronounced peak occurs.

D. *For case* **B** *when Z number is changed by one unit, the separation energy hardly changes (sometimes not at all). But when this number is changed by two units, another pronounced peak occurs. So there are peaks for odd-odd N-Z nuclei (and not for even-even cases).*

Note that for example here we are plotting S_{1n} and S_{2n} as a function of Z for a particular N. Hence while we are pulling one or two N we are studying this as fuction of Z. Thus the above effects cannot be the result of identical nucleon pairings, What these plots are telling us is as to what happens to last one or two neutron bindings in a nucleus as proton number changes.

Clearly the peaks as indicated in **A** above are due to the fact that the last one or two neutrons must have come from a stable alpha cluster. This is consolidated by the fact that another extra Z does not make a difference to the saparation energy.

To understand observation **B** above - note that here the peaks are there for ALL odd-odd N=Z nuclei. This is an amazing fact. These odd-odd nuclei are more stable or "magic" with respect to the adjoining odd-even or even-odd nuclei. Pairing of identical nucleons cannot explain this generic feature. Neither can alpha clustering do so. Obviously it is the formation of triton-helion 'h-t' pair which can only explain this extraordinary effect. This is the minimal requiremet without which one just cannot explain the generic effect indicated in 'B'. Just as alpha clustering explains the extra stability for case **A** so does the formation of 'h-t' cluster pair can only exlain the data in **B**.

What I would like to emphasize here is that the above conclusion is inescapable as per the empirical information manisfested in separtation energy plotted in the manner indicated above. It is Nature which is forcing this conclusion upon us.

To understand observations **C** and **D** we have to undertand new empirical studies on neurton rich nuclei.

Going through the binding energy systematics of neutron rich nuclei one notices that as the number of α's increases along with the neutrons, each ^4He + 2n pair tends to behave like a cluster of two $^3_1H_2$ nuclein [6]. Hence the author had concluded that all light neutron rich nuclei $^{3Z}_{Z}A_{2Z}$ are made up of Z number of $^3_1H_2$ clusters. There are good empirical evidence for this.

Separation energy studies like above support this conclusion too [7]. We

plotted separation energies for neutron number N and for proton number Z fixed separately at 4, 6, 8, 10, 11, 12, 16, 20, 22 and 24. We found extraordinary stabilty manifested by the plotted data for the proton and neutron pairs (Z,N): (6,12), (8,16), (10,20), (11,22) and (12,24). These new magicities were present in the neutron rich sector for the pair (Z,N) where N=2Z.

What is the significance of this extraordianry stabilty or magicity for all the nuclei $^{3Z}_{Z}A_{2Z}$? Quite clearly the only way we can explain the extra magicity for these N=2Z nuclei is by invoking the significance of triton clustering in the ground state of these neutron rich nuclei. So the nucleus $^{3Z}_{Z}A_{2Z}$ is made up of Z number of triton clusters.

To understand this unique feature the author introduced a new symmetry "nusospin" symmetry [7]. Though the thrust of this paper is not this nusospin summetry, the author would like to emphasize that triton and helion clustering effects in nuclei can be understood naturally in the framework of the new nusospin symmetry.

So it is clear that it is tritons which explain the stabilty of neutron rich nuclei and it it is pair of 'h-t' clusters which explain the stabilty of odd-odd N=Z nuclei in the separation energy as plotted above.

Now we can explain the obseravtion **C** above. Clearly for even-even N=Z nuclei it is one (or more) alpha clusters which explain the data. Hence one extra Z does not affect the separation energy. But two extra Z will tend to make a pair of helions (akin to the two tritons for neutron rich case above). These two 'h-h' will make for the extra stabilty for the adjoing even-even nuclei (and so on). So also can the observation **D** be understood as the extra 2Z will create an extra helion to attach to the already existing 'h-t' pair to make for extra stabilty of this adjoining odd-odd nuclei. Other peaks in the above plots can be similarly explained as due to alpha or triton and helion clusters.

The author would like to emphasize that quite obviusly these qualitative conclusions are inescapable and unique. This is true as there is no other way to explain the above empirical observations on the whole.

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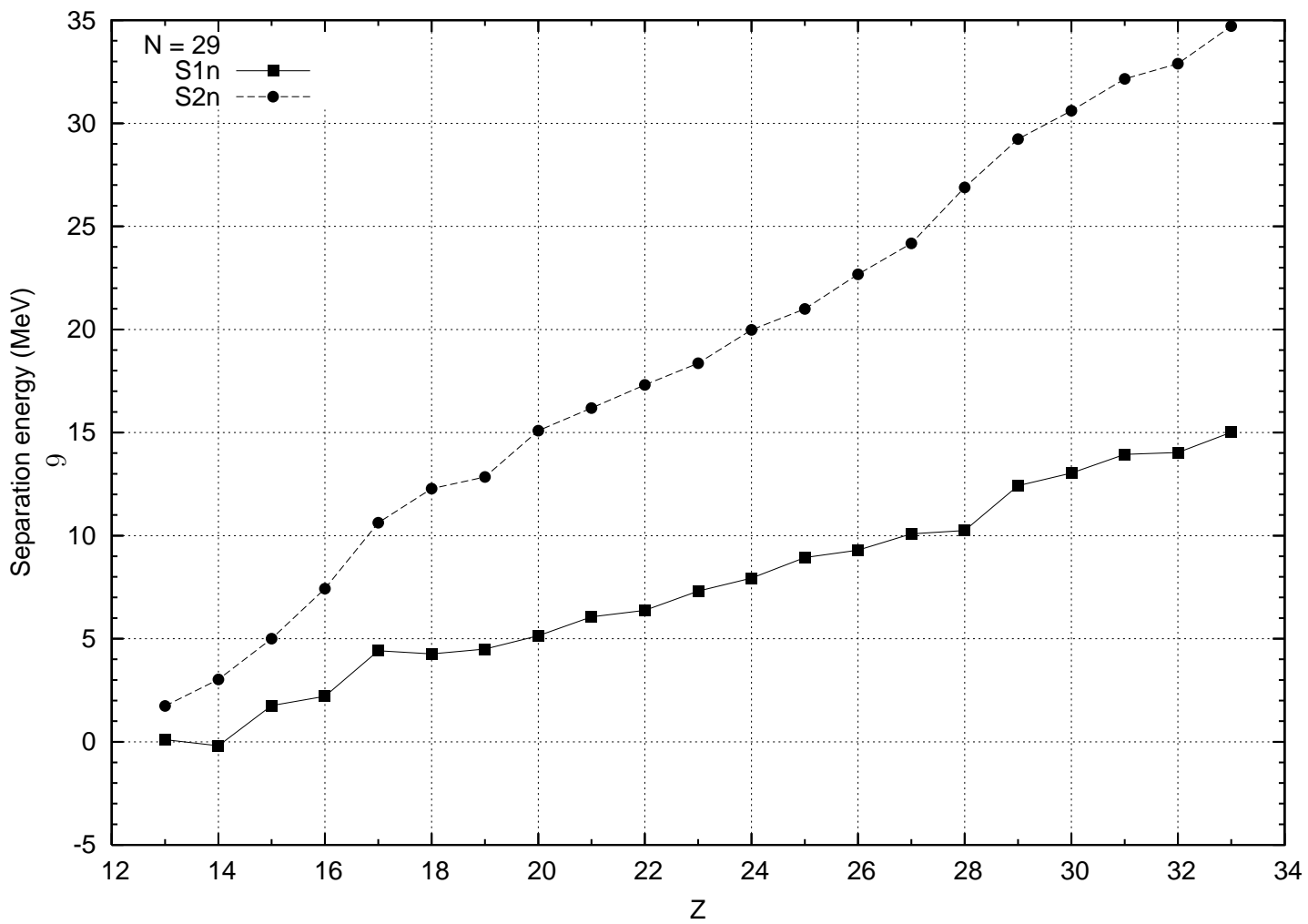7. A, Abbas, Mod. Phys. Lett. **A 20** (2005) 2553

Figure 1: One and two neutron separation energy as a function of proton number Z for fixed N=29 neutrons
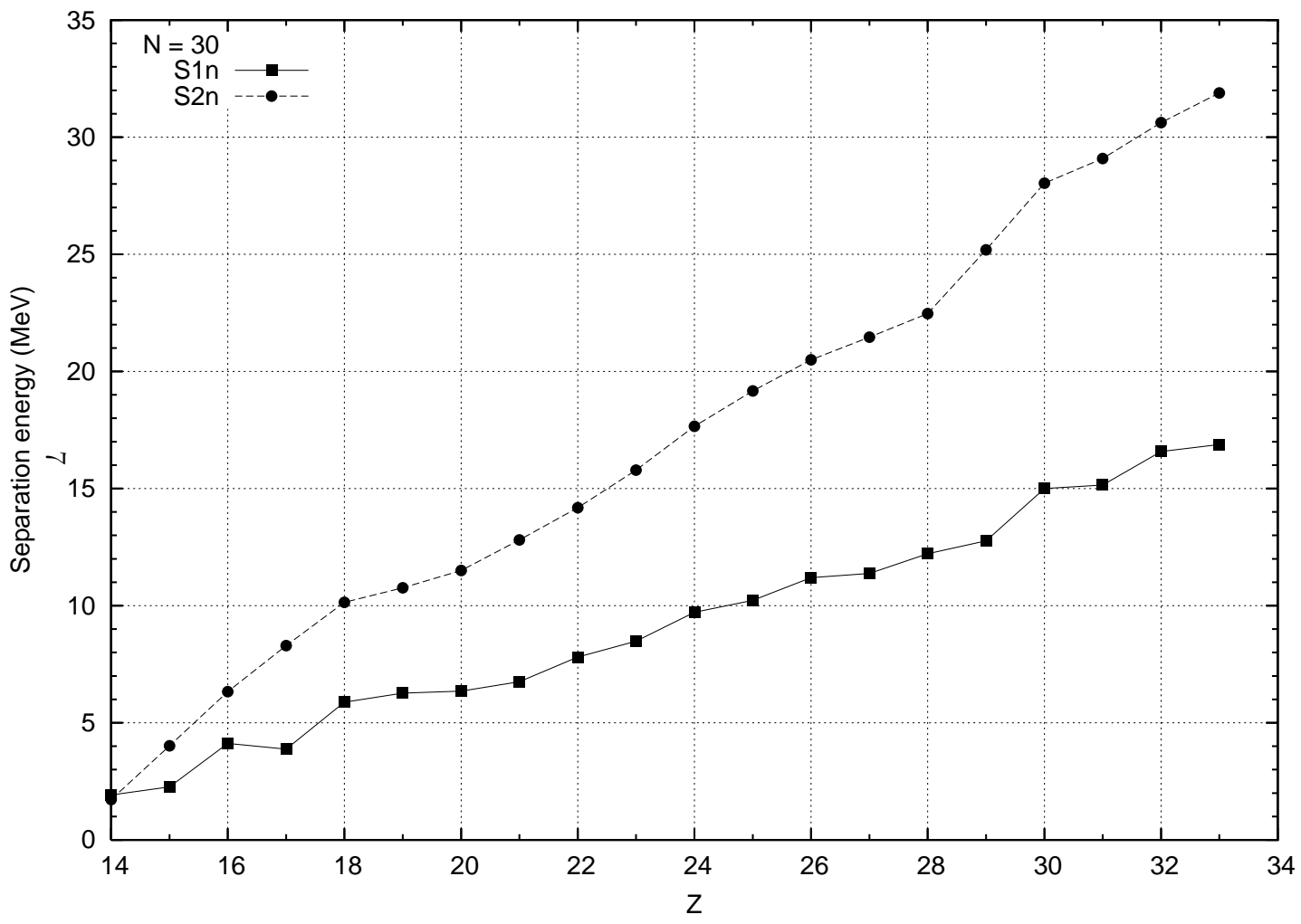
Figure 2: One and two neutron separation energy as a function of proton number Z for fixed N=30 neutrons